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LOCAL AREA NETWORKS WITH FIBER OPTICS

by

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Local Area Networks with Fiber Optics

by

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ABSTRACT

Today's LANs are governed by two sets of standards. First, the IEEE 802 standards address the needs of low and medium speed LANs employing twisted pair and coaxial cable mediums. Second, the Fiber Distributed Data Interface (FDDI) standard addresses the needs of high-speed LANs for backbone connectivity using optical fibers.

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TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

A. BACKGROUND

Local Area Networks (LANs) started as a laboratory curiosity in the mid 1970s. First generation LANs operated at up to speeds of 10 Mbits/s and have been widely deployed into the office environment. Second generation LANs operating at about 100 Mbits/s are the subject of current standardization efforts while third generati‚n LANs operating in the Gbits/s region are under research and development.

At times it is difficult to define just exactly what constitutes a LAN because LANs take many different forms. It is frequently suggested that a digital PABX handling voice and data is a form of LAN. Regardless of the confusion, LANs differ from classical communication systems in that, firstly, a number of users share the transmission medium and, secondly, at least some of the information is sent in packets containing address destinations. Metropolitan Area Networks (MAN) also display similar concept in structure. The primary difference between MAN and LAN is the geographical coverage provided.

LANs connect computers in the same general area. In contrast to MANs, LANs are usually restricted to one building or complex of buildings. Other kinds of computer networks are possible as well. Computers often communicate with each other thousands of miles apart from one another. Typically, these computers are linked by coaxial cables, terrestrial and satellite microwaves, or fiber-optic cables. Computers can also communicate over the public switched telephone network. With a low speed modem, computers can send messages across the country over regular telephone lines. These modems can help access on-line services such as CompuServe, electronic mail, interest group forums and news. However, for day-to-day office computing needs, the best answer is usually a LAN. This thesis is primarily concerned with the LAN systems employing fiber optics and the standards that dictate them. Fiber optics is a transmission technique that uses electrical signals to modulate a light source and produce an optical signal proportional to the electrical signal. This technology possess distinct advantages over conventional copper networks.

Single mode fiber is the present direction of the state-of-the-art technology for LAN systems because of its superior performance. However, multimode fibers have been implemented in LANs successfully since the 1970s. Due to the many strides made by industry in this field, most digital transmissions will be through fiber optic mediums in the future. More vendors are entering the fiber optic market, a trend that translates into acceptance of the technology.

B. OBJECTIVES

This thesis focuses on the broad and constantly changing field of fiber-optic local area networks. Topics of fundamental importance in this thesis are the architecture and standards of those LANs. It will provide the reader with the introductory and tutorial materials and function as a primary reference for those who need an understanding of the technology, implementation, design and application issues that relate to fiber-optic LANs.

The objectives of this thesis are to provide:

- A tutorial of the fiber-optic technology and LAN architecture
- Discussion of relevant LAN standards
- A comparative assessment of alternative LAN standards and options

C. ORGANIZATION OF THESIS

Chapter II gives the reader a brief overview of the OSI reference model in an effort to explain the requirements of computer communications. Then, the LAN architecture is discussed as a means of providing the reader with an understanding of the design issues that must be addressed in implementing and operating local area networks. Chapter II also examines the organizations and their standards that are currently a functional part of the LAN environment.

Chapter III focuses on fiber optics. This chapter explains the benefits and attributes of fiber optic systems, and described are some underlying design considerations.

Chapter IV attempts to bond the two technologies together, fiber optics and local area networks, by first presenting the standards required for the operation of a fiber optic LAN, that being FDDI and then showing how all LAN systems, be they fiber or copper, can be interconnected.

Chapter V is to give the reader a description of a fiber optic system that is in actual operation. This system, currently in operation by the United States Navy, is SAFENET II. This chapter not only shows the integration of technologies discussed in previous chapters but also supports the fact that LAN technology is rapidly becoming the preferred communication method for every facet of the communication environment.

II. LOCAL AREA NETWORKS: ARCHITECTURE AND STANDARDS

A. INTRODUCTION

A structure that allows a data processor to access data processing functions or services at another place can be classified as a computer network. The network consists of a number of nodes, among them the terminal and the computer and includes also the intervening transmission lines connecting the nodes.

Computer users began accessing central processor resources over 30 years ago and, since then, computer networks have become more and more versatile, powerful and complex. Computer networks of today range from a single small processor that supports one or two terminals to a complicated cluster of hundreds of processing units of various sizes that are interconnected to one another and to tens of thousands of terminals.

Networks of today are conceived as a layered architectures. This layered architecture makes it possible to dissect the functions of the network and then explain them one at a time.

The remainder of this chapter is devoted to the understanding of the LAN architecture and standard protocols.

Various concepts and issues related to local area networks are discussed.

B. OSI REFERENCE MODEL AND LAN ARCHITECTURE

1. OSI REFERENCE MODEL

The need for special standards for heterogeneous information networks was recognized by the International Organization for Standards (ISO) in 1977. It was then that the subcommittee for "Open Systems Interconnection" (SC16), was conceived.

Experimental networks, such as ARPANET, fostered the initial development of computer networks, immediately followed by commercial networks. While experimental networks were conceived as heterogeneous from the very beginning, each manufacturer developed its own set of conventions for interconnecting its own equipment, referring to these as its "network architecture".

SC16's sole objective was to come up with standards required for open systems interconnection. The term "open" was chosen to emphasize the fact that by conforming to those international standards, a system will be capable of interacting with all other systems obeying the same standards throughout the world.

After 18 months of deliberation, SC16 presented to its parent Technical Committee (TC97) an ISO model of network architecture called the reference model of the Open Systems

Interconnection. It also recommended to start officially a number of projects for developing a set of standard protocols for open system interconnection.

SC16's objective concerns the standardization of rules of interaction between interconnected systems; therefore, only external behavior of open systems must conform to the OSI architecture. The internal organization and functions of each individual open system is beyond the scope of OSI standards since these are not visible to other systems.

As Figure 1 illustrates, the reference model consists of a hierarchy of seven layers. Each layer uses the layer beneath it to provide a service of a particular character and to provide a more complete service to the layer above it.

a. Physical Layer

The fundamental layer of the OSI model is the physical layer. It provides for absolute physical connection between devices. This layer also covers the rules by which bits are passed from one to another.

b. Data Link Layer

The principale services provided at this layer to higher layers is that of error detection and flow control. If the data link layer protocol is fully functional, error free transmission over the link may be assumed. The data link layer also provides rules for efficient communication by sending blocks of data (frames) with the necessary synchronization, error control and flow control information.

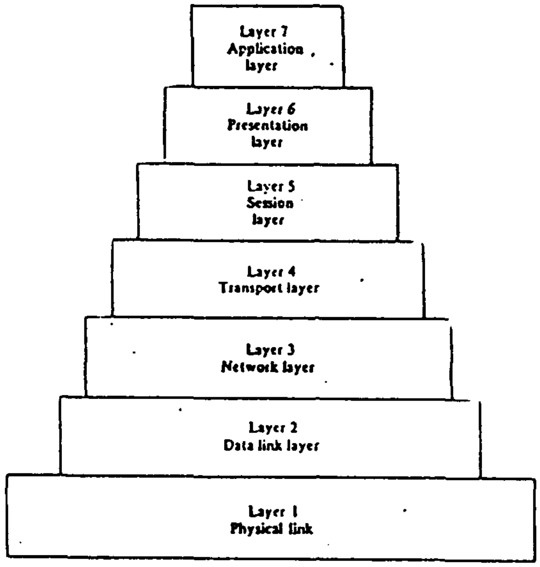

Figure 1. Reference Model. Source (Stallings 1989, p-546)

c. *Network Layer*

The network layer is responsible for establishing, maintaining and terminating connection across the intervening communication facilities. This layer assembles and disassembles data packets during transmission and reception, respectively. Another responsibility of this layer is to maintain priority of packets sent through the network.

d. *Transport Layer*

This layer optimize the use of network services and provides a requested quality of services to session entities. Data units are ensured error free delivery, sequence and with no losses or duplicates. Data is taken from the session layer, the next higher layer in the ISO model, and broken up into smaller units. This data is then multiplexed and put onto the network.

e. *Session Layer*

The session layer provides the following services:

- Establish, manage and terminate connection between cooperating applications
- Provide a interface between hardware and software
- Maps addresses to names

f. *Presentation Layer*

The session layer data is translated or interpreted by the presentation layer to be used by the application layer. When computers are communicating and the application layer is to understand the information transferred by the two dissimilar machines, they must use a common syntax to represent alphanumerics, file formats, data types and character codes. The presentation layer negotiates this syntax. This allows the two machines' application layers to communicate.

g. *Application Layer*

The user is allowed access to the computer through the application layer. This layer contains management functions and generally useful mechanisms to support distributed applications.

2. LAN ARCHITECTURE

OSI dictates that layers one through three are required when using the services of a communications network. For review purposes those layers are the physical, data link and network layers. However, the characteristics of a LAN allow these services to be implemented on the lowest two OSI layers. That is, a LAN's minimum essential communication function corresponds to layers one and two of the OSI model.

As illustrated by Figure 2 and explained below, the functions required for controlling a LAN are:

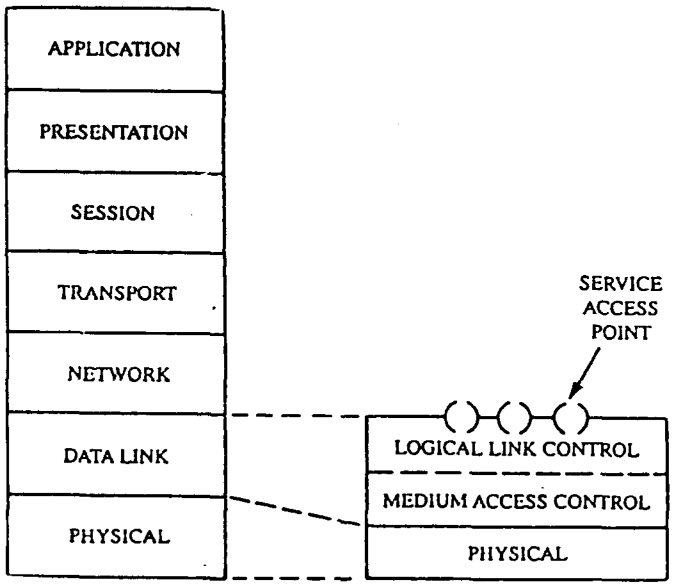

Figure 2. Local Area Network Communication Architecture Compared to OSI. Source (Stallings 1987,p-37)

- Provide one or more service access point (SAP). SAP is a logical interface between two adjacent layers
- On transmission, assemble data into a frame with address and error detection field
- On reception, disassemble frame and perform address recognition and error detection

- Manage communication over the shared transmission medium

The first three functions are typically associated with layer two, the data link layer, and are grouped into a logical link control (LLC) sublayer by IEEE 802. The last function is treated as a separate sublayer called medium access control (MAC). For the same LLC, several MAC options may be provided.

The functions associated with the lowest layer, the physical layer, include:

- Encoding/decoding of signal
- Preamble generation/removal
- Bit transmission/reception

a. Logical Link Control

LLC is concerned with the transmission of frames of data between two stations with no intermediate switching nodes. LLC differs from traditional link layers in the following ways:

- Supports link multiple access
- Provides some layer three functions
- It is relieved of some details of link access

Figure 3 is presented to help clarify the requirements for the LLC layer. The higher layers of two stations, communicating via a LAN, provide end-to-end application services between the two stations. Below the LLC layer, a MAC layer provides the necessary logic for gaining access to the network for frame transmission and reception. At a minimum, the LLC layer should perform the following functions normally associated with the OSI data link layer:

- Error control
- Flow control

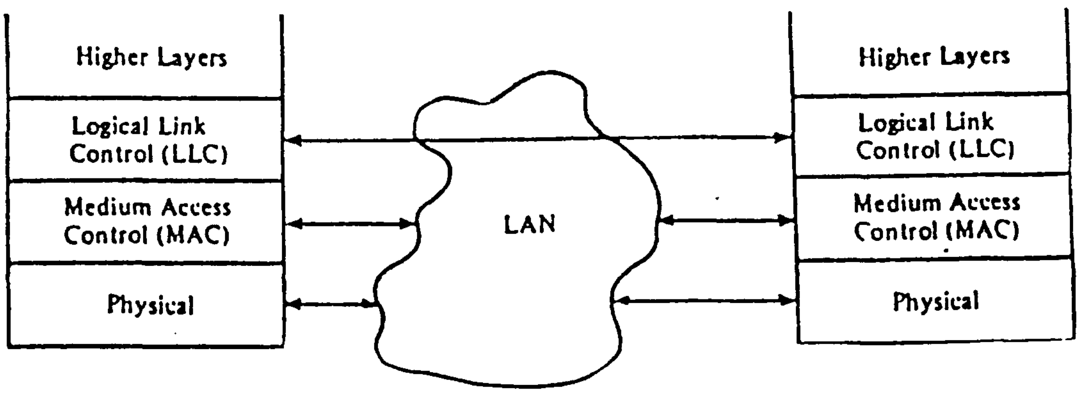

Figure 3. LAN Communication Architecture
Source (Stallings 1987,p-40)

b. Medium Access Control

As a means of controlling the shared network transmission medium, any medium access control technique can be characterized by two parameters: where and how. "Where" implies whether control is either centralized or decentralized. In a centralized scheme, a controller is designated to authorize access to the network. Permission must be received from the controller if a station wants to transmit. In a decentralized scheme, the medium access function is collectively performed by stations.

The second parameter, "how", determines whether the medium access control is synchronous or asynchronous. The preferred method is asynchronous. Asynchronous techniques, more or less, responds to the immediate needs of the user. (Stallings 1987,p-39)

Figure 4 describes the format of LLC and MAC protocols data units. A header is appended to the user data when it is passed down to the LLC. The header contains control information. The user data and LLC header combined are referred to as LLC protocol data unit (PDU). The PDU is then passed down to the MAC entity. In order to manage the MAC protocol, a header and a trailer is appended to the PDU. This results in a MAC-level PDU. A destination address that uniquely identifies a station on the network is contained in the MAC header. This is needed because each station on the local network will read the destination address field to determine if it should capture the MAC frame. Once a MAC frame is captured, the header and trailer are striped off and the LLC PDU is passed up to the LLC entity. In order for the LLC to determine to whom data is to be delivered, the link header must contain a service access point (SAP). (Stalling 1987,p-43) Therefore two levels of addressing are needed:

* MAC address, identifies a station on the local network
* LLC address, which identifies a LLC user

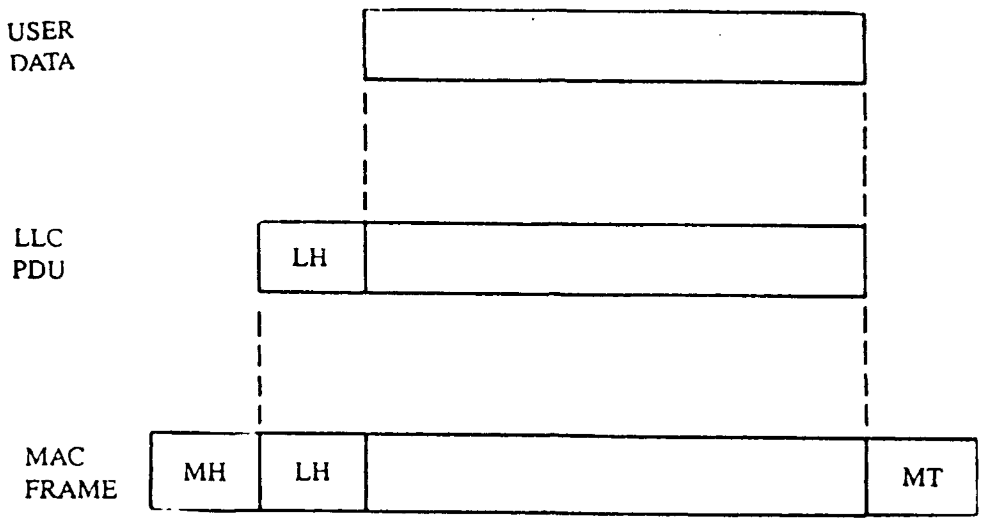

Figure 4. Local Network Protocol Data Units
Source (Stallings 1987,p-43)

c. *Physical Layer*

The four principal characteristics that make up the physical layer are mechanical, electrical, functional and procedural.

The mechanical aspect include things such as, the specifics of the connector, interchange circuits, the connector latching arrangement, mounting arrangement, etc.

The electrical aspect specify the characteristics of the generators and receivers and give guidance with respect to the interconnecting cable.

Interchange circuit functions are typically classified into the following broad categories: data, control, timing and ground.

The final aspect of the physical layer is the set of procedures for using the interchange circuit. Those procedures are the ones that need to be performed to enable the transmission of bits so that the higher level functions can take place.

C. LAN STANDARDS

1. Introduction

In the past, the computer industry did not accept the standards for computers and communication, making it virtually impossible to interconnect computers for interoperability. Computer manufacturers and software vendors understand that different computers must communicate with each other and, with the ongoing evolution of protocol standards, customers will no longer accept special purpose protocol conversion software developments. Listed below are some of the advantages and disadvantage of standardization.(Stallings 1987,p-31)

<u>Advantages</u>

- Gives purchaser flexibility when multiple producers can communicate
- Equipment or software are assured a large market
- Mass production is encouraged

Disadvantage

• Technology is frozen

LAN standards ensure a high volume market for chip producers by enabling equipment of a variety of manufactures to intercommunicate.

2. Organizations For LAN Standards

IEEE 802 committee sponsored by the IEEE Computer Society and the X3 committee, both of which are accredited by ANSI, are the main groups involved in the development of local area network standards. Each group's underlining goal is to develop standards that are adopted by the International Organization for Standards (ISO).

a. *ISO*

The ISO is an international agency whose members are composed of participating nations and nonvoting observer organizations. ANSI is the United States' representative.

More than 5000 standards have been issued since ISO's conception in 1946. Issues ranging from screw threads to solar energy have become standards. Its purpose is to promote the development of standardization and related activities to facilitate international exchange of good and services, and to develop cooperation in the sphere of intellectual, scientific, technological and economic activity.

The ISO can further be dissected into subcommittees. Technical committee 97(TC97), Information

Processing Systems, is the subcommittee of relevance to this thesis. TC97 also is organized into subcommittees. Subcommittee SC16 and SC21 work on OSI related subjects.

b. ANSI

The American National Standards Institute is the designated voting member for the United States during ISO meeting. National standards are published by ANSI, but standards are not developed by this organization. Instead, standards are developed by other groups that are accredited to develop standards for ANSI consideration. One such group is the Accredited Standards Committee(ASC) X3. Standards relating to information processing are developed by ASC X3.

c. IEEE

The world's largest professional society is IEEE. It is composed of some 275,000 members. Standards are developed by IEEE and submitted to ANSI for consideration as a national standard.

The IEEE 802 committee is organized in the following subcommittees:

- 802.1: high level interface
- 802.2: logical link control
- 802.3: CSMA/CD networks
- 802.4: token bus networks
- 802.5: token ring networks
- 802.6: metropolitan area networks

- 802.7: broadband technical advisory group
- 802.8: fiber optic technical advisory group
- 802.9: integrated data and voice networks

Each subcommittee continues to work on new options and features. 802.1 deals with issues related to network architecture and internetworking. Earlier discussion on architecture and addressing is based on the work of this subcommittee. 802.6 is now in the process of developing a small number of reasonable alternatives for their area of study. The purpose of 802.7 and 802.8 is to provide technical guidance to the other subcommittees on broadband and optical fiber technology, respectively. The newest subcommittee, 802.9, is developing an interface standard for desk-top devices to 802 LANs and to Integrate Services Digital Network (ISDN) that utilizes twisted pair wiring to carry voice and data.

Although the study being conducted by these subcommittee is interesting, it is beyond the scope of this thesis. The subcommittees of relevance however are 802.2, 802.3, 802.4 and 802.5. The remainder of this chapter examines the new options features and developments of these subcommittees along with Fiber Distributed Data Interface (FDDI).

3. IEEE 802.2 Logical Link Control

LLC's primary purpose is to provide a means of exchanging data between LLC users across a MAC controlled link. All MAC standards specified by IEEE 802 and FDDI use above them LLC.

a. *LLC Services*

The services provided by LLC to its users are:

- Unacknowledged connectionless mode
- Connection mode
- Acknowledged connectionless mode

(1) Unacknowledged connectionless mode. Unacknowledged connectionless service allows the LLC user to exchange data in accordance with a prior agreement made between LLC user in different systems. To initiate the transmission of data unit, a service access is required. Data presented by one user is not guaranteed delivery to another user by the service provider, nor is the sender informed of delivery attempts or failures. Furthermore, if data units are delivered, there is no guarantee that they will arrive in the same order in which they were sent. Unacknowledged connectionless service can provide delivery to one user (point-to-point), delivery of copies of data unit to multiple users (multipoint) and

delivery to all active users (broadcast).(Stalling 1987,pp57-58)

(2) Connection Mode. With connection mode service, three phases occur when a logical connection is established between two LLC users:

- Connection establishment
- Data transfer
- Connection termination

(3) Acknowledged Connectionless. Acknowledged connectionless service provides for the immediate acknowledgement of each transmitted data unit. The LLC service provider will only send data units one at a time; that is, each transmitted data unit must be acknowledged before the next one is transmitted. This service is only point-to-point. (Stalling 1987,pp64-66)

b. Link Control Protocol Mechanisms

The fundamental task of any link control protocol involves the interchange of information between sender and receiver over a given interconnecting link. Two of the most important mechanisms used in link control protocols are flow and error control. (Stalling 1988,pp127-128)

(1) Flow control. Data transfer rates are limited with the aid of flow control. At the transport level, the receiver most often limits the originating station's

activity. Simple flow control may be achieved with start and stop commands issued from the receiver. However, in the absence of flow control, the receiver's buffer may fill up and overflow while it is processing old data. If the amount of data to be transmitted is agreed upon by the transmitter and receiver before hand, much more effective flow control techniques can be employed.

(2) Error Control. All network transmissions must have a negligible amount of errors. The network layer may demand transmission of data with error correction. The most common techniques for error control are based on two functions:

- Error detection: PDUs are discarded once the receiver detects an error
- Automatic repeat request(ARQ): When an error is detected, the receiver request frame retransmission

The use of these approaches have resulted in the conversion of a unreliable data link into a reliable one. At present the most popular ARQ employed by LLC standards are, stop-and-wait ARQ and go-back-n ARQ. (Stallings 1988,p-141)

The stop-and-wait technique, which is the simplest form of error control, works as follows: the receiver sends a poll, which indicate a willingness to accept data. Data is then transmitted from the sender. After the data has been received, the receiver must again indicate its willingness to accept data before more is sent.

In the Go-Back-N variant of ARQ, a station may send a series of frames which are determined by window size. If a error is detected by the receiver, it sends a non-acknowledgement for that frame. All future incoming frames are discarded until the frame in error is correctly received. Once a NAK is received from the transmitting station, it must retransmit the frame in error plus all succeeding frames.

c. *LLC Protocols*

The LLC protocol is modeled after the High-level Data Link Control (HDLC) balance mode and has similar functions and formats.(Stallings 1987,p-75) For each of the three forms of services, unacknowledged connectionless, connection mode and acknowledge connectionless service, there is a LLC protocols. The protocols are referred to as types.

The same protocol data unit (PDU) format is employed by all three LLC protocols. The format consist of four fields. There are two eight bit address fields, the destination service access point (DSAP) field and the source service access point (SSAP) field. Each address field consist of a seven bit address and a control bit. In the DSAP the address type is indicated by the control bit. In the SSAP the control bit indicates whether this PDU is a command or a response.

(1) Type One Operation. Unacknowledged connectionless service is supported by type one operation using three unnumbered PDUs; UI, XID and TEST. The UI PDU information field contains the destination address of the data parameter to be transmitted. Because there is no acknowledgement of flow and error control, there is no guarantee that a UI PDU will be successfully received.

(2) Type Two Operation. Connection mode service is supported by type two operation and makes use of three PDU formats:

- Information transfer: used to transfer user information
- Supervisory: used for acknowledgement, flow and error control
- Unnumbered: used for connection establishment, connection *termination and other control functions*

(3) Type Three Operation. With type three operation each transmitted PDU is acknowledged. Two new unnumbered PDUs are defined: acknowledged connectionless, seq. 0 (ACO) and acknowledged connectionless, seq.1 (AC1); when the distinction is unimportant both will be referred to as ACN. The encoding of the two PDUs differ only in one bit position. Unlike the other PDUs used in LLC, the ACN PDUs are not defined in HDLC. User data is sent in an ACN command PDU and must be acknowledged using an ACN response PDU. To guard against lost PDUs, the sender alternates the use of ACO and

AC1 in its command PDUs, and the receiver responds with an ACN PDU with the opposite number of the corresponding command. Stop-and-wait flow control and stop-and-wait ARQ error control are used. (Stallings 1988,p-141)

4. IEEE 802.3 CSMA/CD

Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is the most commonly used MAC technique for bus/tree topology, which is defined by IEEE 802.3 standards. The standards are divided into two layers, the MAC layer and the physical layer specifications.

Services provided to the MAC level user and the MAC protocols are defined by the MAC layer specifications. These specifications include identifying the means for transmitting and receiving PDUs or data frames. Additionally, this service specification hides unnecessary details of the MAC and physical layer from the user. The specifications also define the frame structure and the interaction between MAC entities.

According to the standards (Stallings 1987,p-88), the rules for this protocol follow the steps listed below.

1. If the medium is idle, transmit PDU; otherwise, go to step two.
2. If the medium is busy, continue to listen until the medium is sensed idle; then transmit immediately.
3. If there is a collision, transmit a brief jamming signal to assure that all stations know that a collision has occurred and cease transmission.

4. After transmitting a jamming signal, wait a random amount of time and return to step one.

The standards also describe a parameter called a time slot. The time slot is the time it takes for a signal to travel from one end of the medium to the other and back. The time is dependent on the medium used.

The format of the IEEE 802.3 MAC frame is depicted by Figure 5 and described below. (Stallings 1987,pp91-92)

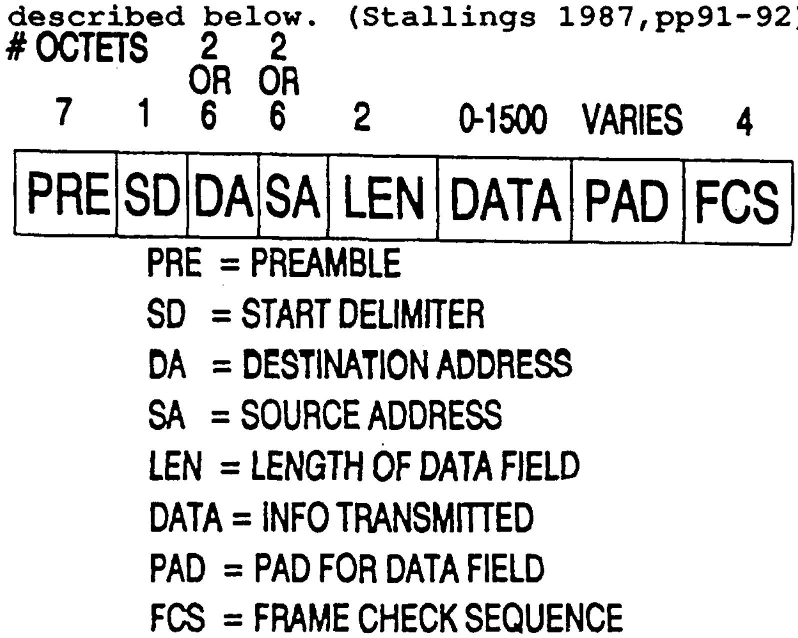

Figure 5. IEEE 802.3 Data Frame Format

- Preamble: a seven byte pattern used by the receiver to establish bit synchronization
- Start Frame Delimiter(SFD): indicates the start of the frame
- Destination Address(DA): specifies the station(s) for which the frame is intended
- Source Address(SA): specifies sending station
- Length: specifies the number of LLC octets that follow

- Data: data unit supplied by LLC
- PAD: assures frame is long enough
- Frame Check Sequence(FCS): a 32 bit field used for error detection

The physical layer specifications are divided into two parts, the medium independent and medium dependent specifications. The interface between MAC and physical layer are specified by the medium independent part and the actual LAN medium is referred to by the medium dependent part.

Because IEEE 802.3 standards specify the use of coaxial and twisted pair to be used as the attachment interface, this thesis does not go into details of the physical layer specifications. However, Table I is provided to show the key parameters of the medium specifications.

As of date, IEEE has not yet specified the standards for fiber optics as a medium for the bus/tree topology. Because of the increased use of fiber optics as a physical medium, it is expected that IEEE, in the near future, will develop standard that will fit the needs of the CSMA/CD users.

5. IEEE 802.4 Token Bus

The IEEE 802.4 standards define token passing MAC protocols for the bus topology. The standard also define the physical layer transmission medium and data rates.

Table I IEEE 802.3 PHYSICAL LAYER ALTERNATIVES

PARAMETER	10BASE5	10BASE2	1BASE5	10BROAD36
Transmission medium	Coaxial	Coaxial	Twisted pair	Coaxial
Signaling technique	Baseband (Manchester)	Baseband (Manchester)	Baseband (Manchester)	Broadband (DPSK)
Data rate (Mbps)	10	10	1	10

The token bus technique is similar to CSMA/CD bus but more complex. For this technique, the station on the bus or tree form a logical ring as depicted by Figure 6. The stations are assigned logical positions in a sequential order with the last member of the sequence followed by the first. The identity of the station preceding and following a station is known by each station.

The right of access is regulated by a control frame known as the token. The destination address is contained in the token frame. Control of the medium is granted to the station receiving the token for a specified amount of time. When time has elapsed or the transmission is complete, it passes the token on to the next station in logical sequence. Now this station has permission to transmit.

Considerable maintenance is required for this scheme. At a minimum, the following functions must be performed.

* Ring initialization: Start up or break-down requires ring initialization

* Addition to ring: Non-participating stations are periodically granted insertion into the ring

* Deletion from ring: A station must be able to remove itself from the ring by splicing together its predecessor or successor

* Recovery: Errors such as duplicate token and lost token must be taken care of

* Priority: The token bus scheme lend itself to the use of dynamic capacity allocation technique

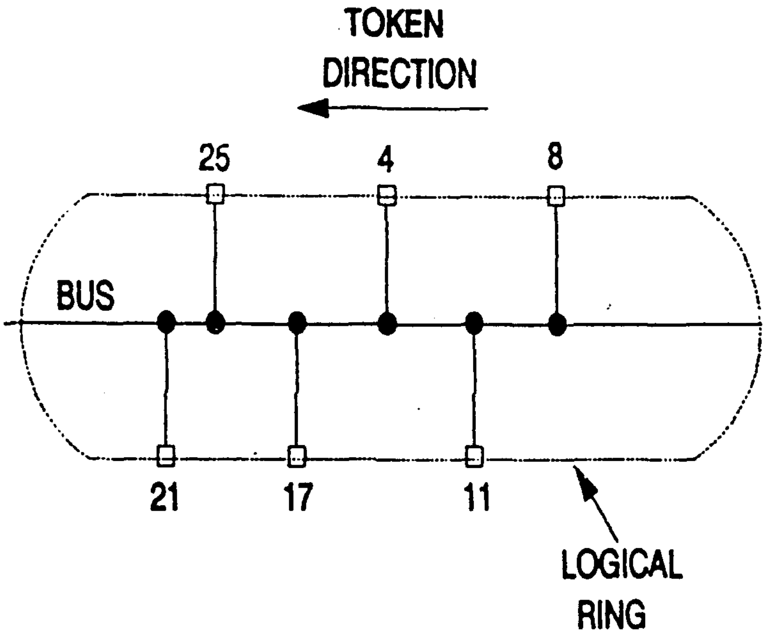

Figure 6. IEEE 802.4 Token Bus Node Source (Hunninghake,p-84)

The MAC frame structure for token bus is illustrated by Figure 7 and explained below.

* Preamble: receives uses to establish bit synchronization and locate first bit of the frame

* Start Delimiter(SD): indicates start of frame

* Frame Format(FF): indicates whether or not this is an LLC data frame

* Destination Address(DA): same as CSMA/CD
* Source Address(SA): same as CSMA/CD
* LLC: LLC prepared field
* Frame Check Sequence(FCS): same as CSMA/CD
* End Delimiter(ED): indicates end of frame

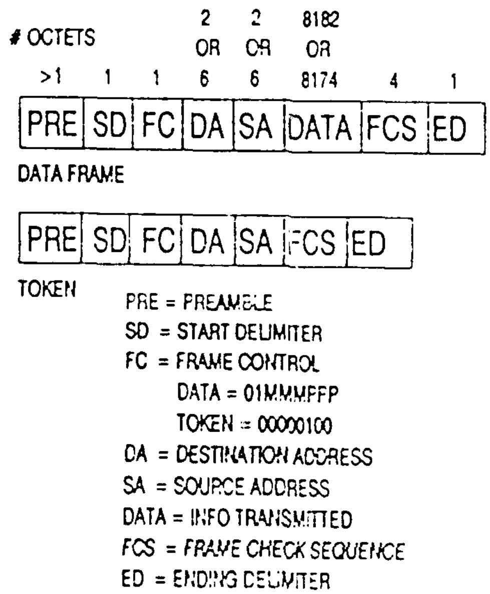

Figure 7. MAC Frame

Here again the standards for the use of fiber optics have not yet been developed by IEEE. At present, IEEE 802.4 specifies three alternatives to be used as a physical medium for this topology. The details of those alternatives are provided below in Table II.

6. IEEE 802 5 Token Ring

The IEEE 802.5 standards define the token ring medium access control (MAC) protocol for the ring topology. It also defines the physical layer specifications which are based on

Table II IEEE 802.4 PHYSICAL MEDIUM ALTERNATIVES

PARAMETER	PHASE CONTINUOUS	PHASE COHERENT CARRIERBAND	BROADBAND
Data rate (Mbps)	1	5 10	1 5 10
Bandwidth (Mhz)	N/A	N/A N/A	1.5 6 12
Modulation	Phase continuous FSK	Phase coherent FSK	Multilevel duobinary AM/PSK
Topology	Omnidirec-tional bus	Omnidirec-tional bus	Directional bus (tree)
Transmission Medium	75-ohm coaxial cable	75-ohm coaxial cable	75-ohm coaxial cable

twisted pair differential manchester signaling.

The heart of the 802.5 standards is the MAC protocol. The protocol is based on the use of a token frame. The token circulates around the ring until it is captured by a node with data to transmit. The station seizes the token by changing one bit in the token, which transforms it from a token to a start-of-frame sequence for a frame. Now the station can append and transmit the remainder of the fields needed to control a frame.(Stallings 1987,p-150) Figure 8 depicts this process.

Once the token is placed back on the ring, other nodes can capture it and transmit data. If the next node has no data to transmit, the token is simply passed on.(Stallings

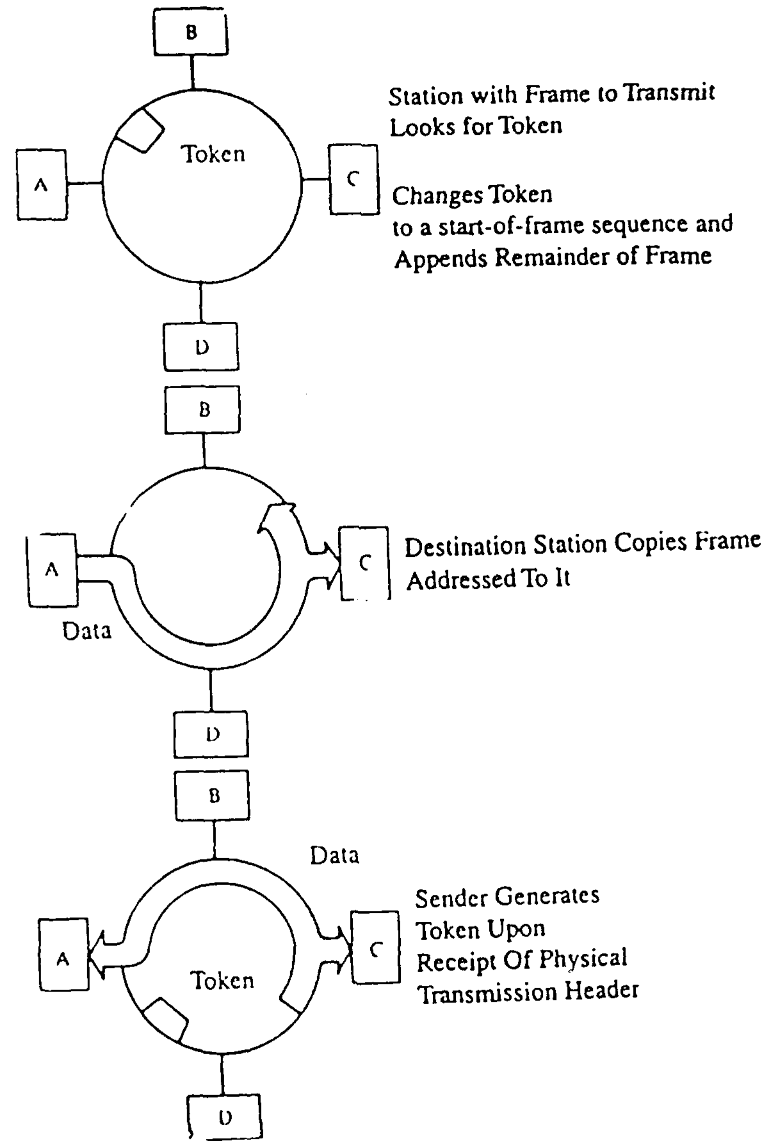

Figure 8. Token Ring. Source (Stallings 1987,p-151)

1987,p-150)

Figure 9 depicts the IEEE-specified field format for data frames, the details of which are explained below:

OCTETS

1	1	1	2 OR 6	2 OR 6	> 0	4	1	1
SD	AC	FC	DA	SA	INFO	FCS	ED	FS

SD = START DELIMITER
AC = ACCESS CONTROL
FC = FRAME CONTROL
DA = DESTINATION ADDRESS
SA = SOURCE ADDRESS
INFO = INFORMATION FIELD
FCS = FRAME CHECK SEQUENCE
ED = ENDING DELIMITER
FS = FRAME STATUS

Figure 9. IEEE 802.5 MAC Data Frame Format

- Start Delimiter(SD): a unique eight bit pattern used to start each frame
- Access Control(AC): has the form "PPPTMRRR", where PPP and RRR are three bit priority and reservation variable, M is the monitor bit, and T indicates whether this is a token or data frame. If it is a token, an additional ED field is added
- Frame Control(FC): indicates whether this is an LLC data frame
- Destination Address(DA): same as CSMA/CD
- Source Address(SA): same as CSMA/CD
- Info: same as CSMA/CD
- FCS: same as CSMA/CD
- Ending Delimiter(ED): contains the error detection (E) bit

- Frame Status(FS): contains the address recognized (A) and frame copied (C) bit

The operation of the system is fairly simple. When a station wants to transmit, it waits until a token passes. The station seizes the token by setting the token bit in the access control (AC) field to one, and appending the remaining fields (FC,DA,SA,INFO,ED, and FS) to the SD and AC field to form a complete transmitted frame.(Stallings 1987,p-156) At the same time the ED field of the captured token is absorbed and discarded by the station. The transmission of data can continue by this station until time expires to hold the token or no more data is left to transmit. More than one frame may be transmitted by the station by setting the I bit in the ED field to one on all but the last frame.

The physical specification are separated into two portions. The medium independent and medium dependent portion. The medium independent portion specifies the use of the following specification:(Stallings 1987,p-169)

- one or four Mbps data rates
- differential manchester technique for signal encoding
- one bit time delay at each node

The medium dependent portion of the standard simply specifies the use of two 150-ohm shielded twisted-pair wires to be uses as the transmission medium.

7. FDDI

Fiber Distributed Data Interface (FDDI) is currently being developed by Accredited Standards Committee (ASC) X3T9. This standard specifies the services and capabilities of the physical and MAC layer of a high speed LAN. FDDI LANs may be used as a stand alone LAN or operated as a high speed backbone connecting several lower speed LANs. The standard calls for a 100 Mbps LAN using fiber optic cable as the transmission medium. Due to the relevance of FDDI, details will be discussed in Chapter IV.

III. FIBER OPTIC TECHNOLOGY

A. INTRODUCTION

The late 1970s marked the emergence of fiber optic technology from the research labs into the telecommunication industry. Before this time, telecommunication systems depended on advances in electronics to provide new capabilities, increased performance, and lower cost. Since then, the communication technology has seen many major developments. Paramount of these is the use of fiber over copper conductors to transmit information and interconnect computing devices. As we shall see, the advantages of fiber over traditional conductor are many. Computer networking has built upon those advantages in fiber optic technology which allows higher bandwidth and extremely low error rate.

Fiber optic local area networks are now being implemented at an increasing rate. As for wide area networks, common carriers have installed a significant portion of their digital backbone networks with fiber. For example, US Sprint has deployed all fiber networks for its voice and data communication services.

In this chapter we examine the advantages of fiber, the topology that employs fiber and finally fiber optics itself.

B. WHY FIBER OPTICS

The purpose of using fiber optic cable in a local area network (LAN) is, by replacing the existing copper cable, to increase data rate, to provide noise immunity, and to reduce the size and weight of the transmission medium. The remainder of this section is dedicated to the examination of the above benefits. It is hoped that an explanation of these factors will give the reader a better understanding of fiber optics.

1. Bandwidth

The greatest attraction of fiber optic technology is the bandwidth of light transmission. Information carried over a carrier wave can be transmitted at a tremendous rate. The bandwidth for multi-mode and single-mode fiber is one 100 Ghz over one kilometer. The channel capacity of a transmission medium, or the maximum rate at which information may be transferred with negligible error, is determined by communication theory. In a classic result due to Shannon, the maximum error-free information transfer rate (in bits per second) achievable on a single channel increases directly with the bandwidth of the channel.(Suematsu, p-77)

A noise-free 1.55 micron wavelength carrier (a standard transmission wavelength) theoretically is capable of carrying hundreds of tera bits of data per second.(Suematsu,pp77-79) This is the equivalent to 1.5 billion simultaneous telephone calls or 1.6 million TV channels on a single fiber. (Barnoski, p-103) However, realistically, fiber is subject to physical effects such as refractive index profiles, material properties and dispersion. For this reason the highest data rate achieved to date is approximately eight gigabit/sec, and the longest distance for coherent transmission is 290 km. (Freeman, p-572)

2. Immunity to Electromagnetic Interference

Optical fiber is not affected by electromagnetic interference or noise. This is because the cladding and inner jacket of the fiber traps the optical wave within the cable. This prevents any leakage out during transmission and interference from external sources.

3. Cost and Weight of Fibers

In this subsection we examine the cost and weight of a single fiber and at the same time make some comparison to copper. The weight of a single fiber is about five oz/km, and the cost is approximately $.30/m or $300/km. This of course depends on the thickness of the cladding. (Freeman, p-572) The transmission capacity of fiber is roughly 15,000 times greater than a copper cable of the same size, and the weight of fiber about 120 times less than a copper cable of equivalent information-carrying capacity. (Palais, p-21) As we go further into the 1990s and fiber becomes more of a household item, it is expected that the cost per bit-kilometer to transmit information will continue to decrease.

C. OPTICAL FIBER AS A TRANSMISSION MEDIUM

Many important aspects determine the nature of a LAN. However, the principal technological ingredients are:

- Medium access control (MAC) technique
- Transmission medium
- Topology

These technologies together determine the efficiency and speed of a network. MAC technique was discussed in an earlier chapter and topologies will be discussed in detail in later chapters. The remainder of this chapter is dedicated to examining transmission media, that, within the state of art, are appropriate for local networks.

Fiber optics offers the most exciting developments in the realm of local network transmission media. The achievement of low-loss transmission coupled with other advantages such as high bandwidth, small size and weight and electromagnetic interference immunity has literally created a new technology for network communications.

In this section we describe this media using the following set of characteristics of optical fiber:

- Physical description
- Transmission characteristics
- Light source and detector
- Connectivity

• Geographic scope

1. **Physical Description**

Simply stated, we can say that optical fiber is a thin (2 to 125µn), flexible medium capable of conducting an optical ray. (Palais, pp165-166) Although various glasses can be used to make optical fiber, ultrapure fused silica offers the lowest losses. Plastic and multi-component glass fiber are less expensive than that of ultrapure fiber because this material is difficult to manufacture.

The optical fiber cable, which is illustrated by Figure 10, is cylindrical in shape and consist of three

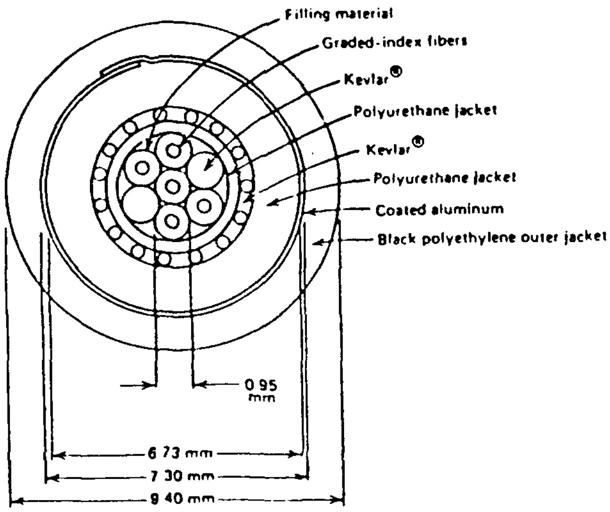

Figure 10. Optical Fiber Cable. Source (Freeman, p-572)

sections, the core, cladding and jacket. The inner most section is the core which consist of one or more thin fibers made of glass or plastic.

The cladding is the next outer-most section which is simply a glass or plastic coating that has optical properties different from the core. The outer-most section is the jacket. Its job is to protect against moisture, abrasion, crushing and other environmental danger.(Palais, p-166)

2. Transmission Characteristics

As depicted by Figure 11, there are three categories of fiber:

- Single mode
- Step index (multimode)
- Graded index (multimode)

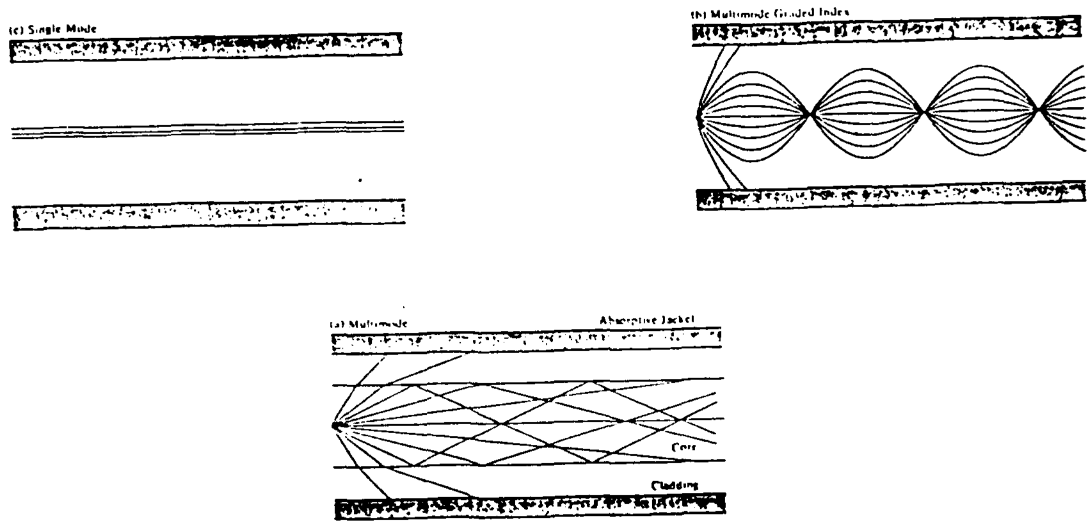

Figure 11. Types of Fiber Optic Cable. Source (Stallings 1987,p-11)

With single mode fiber, a single encoded beam of light is transmitted by means of total internal reflection.

Reflection occurs at any transparent medium that has a higher index of refraction than the surrounding medium. (Freeman, p-572) No modal dispersion exist with single mode fiber, since only one mode is propagated.

Step index fiber is characterized by an abrupt change in refractive index, and graded index fiber is characterized by a continuous and smooth change in refractive index. Graded index fiber is much more expensive than step index but, with graded fiber, the distance product improves.

3. **Light Source and Detector**

The function of a light source in a fiber optic communication system is to efficiently covert electrical energy(current) into optical energy (light). (Suematsu, p-77) The light signal must accurately track the input electrical signal so that noise and distortion are minimized.

The two most common used light sources employed by fiber optic systems are light emitting diode(LED) and injection laser diode (ILD). Although both are fabricated from the same basic semiconductor compounds, they do differ in their performance characteristics.

LEDs operate at greater temperatures, has a longer operation life and are less costly than ILDs. ILDs are more efficient and can sustain greater data rates. (Palais, p-127) The output spectrum of a LED is broad while ILDs have a narrow output spectrum. LEDs are capable of launching about 100μw of optical power into the core of a fiber. (Palais, p-128) A laser diode with the same input power can couple up to seven μw into the same cable. (Suematsu, p-79)

The most common detector for fiber optic communication systems are two solid state photo-diode devices known as PIN detector and APD detector.

PIN is derived from the semiconductor construction of the device where an intrinsic (I) material is used between the p-n junction of the diode. (Freeman, p-572)

The Avalanche Photodiode, which is abbreviated APD, is used to improve photo sensitivity. An APD utilizes carrier multiplication in the high electric field region adjacent to the junction, through impact ionization by accelerated carriers.

Photo-diodes are simply photon counters, and must posses the following characteristics:

- wide bandwidth or high speed response
- small additional noise
- modest source voltage requirements
- high sensitivity

4. Connectivity

Although experimental multi-point systems using a bus topology has been built, the most common use of optical fiber is for point-to-point links. Multi-point systems are too expensive to be practical. There is one approach, however, to multi-point use of optical fiber that is commercially feasible. This approach is referred to as the passive star coupler. Physically this topology has a star configuration, but logically it is a bus topology.

For obvious reasons, it is very important to be able to interconnect optical fiber. But the operation of doing so is potentially difficult because of the very small core size. There are two methods of connecting fiber sections in tandem and connecting the fiber to the source at one end and to the optical detector at the other end.(Palais,p-167) These methods are splicing and special connectors.(Palais,p-171) The transfer of as much light as possible is the underlining goal of both.

There are two types of splices, mechanical and fusion splices. Mechanical splicing involves matching a substance similar to the core fiber. The substance must have a refractive index closely matching the index of the core fiber.(Palais, pp168-169) With a fusion splice, the fibers are butted together and then heated with a flame or electric arc until softening and then fusion occurs. Splicing technique, depending on the type of fiber, incur losses of about .05-.2db.

Connectors tend to pose more of a problem than splicing. Particularly if dirt or dust deposit occur in the area of the fiber. Additionally, connectors losses are higher and their installation more costly.

5. Geographic Scope

Distances of six to eight kilometers without repeaters can be supported by today's technology. Therefore, fiber optics is suitable for linking local networks in several buildings via point-to-point links.

IV. FDDI LOCAL AREA NETWORKS

A. INTRODUCTION

The Fiber Distributed Data Interface is a standard for a high-speed fiber-based token ring local area network. Both the MAC layer and physical layers are encompassed in this standard. Note that the IEEE 802.2 Logical Link Control standard is assumed to be used with this standard. As Figure 12 depicts, the standard is in four parts:

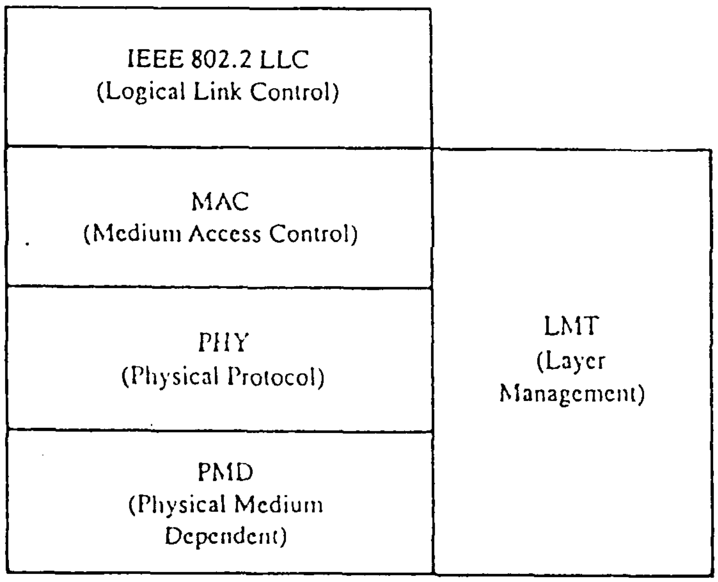

Figure 12. FDDI Architecture. Source (Stallings 1987,p-176)

- Medium access control
- Physical protocol
- Physical medium dependent
- Layer management

The MAC layer is specified in terms of the MAC protocol and MAC services. The heart of FDDI is the MAC protocol. Frame structures and interaction are defined by these specifications. The MAC service specifications defines, in functional terms, the services provided by FDDI to LLC.(Stallings 1988, p-176)

B. FDDI MEDIUM ACCESS CONTROL

1. MAC Protocol

Like that of IEEE 802.5, FDDI MAC protocol is a token ring. The two standards are very similar in terms of operation. The major difference is in the way in which capacity is allocated on the ring. The FDDI approach is designed to take advantage of the high speed(100 Mbps) of its ring and to maximize efficiency.

a. *MAC Frames*

To better understand the MAC protocol, let us first examine the frame structure. The structure is expressed in terms of symbols exchanged between MAC entities. Each symbol corresponds to four bits. As depicted by Figure 13 and explained below, the overall format consist of the following fields:

- Preamble: synchronizes the frame with each station's clock
- Start Delimiter(SD): indicates the start of the frame
- Frame Control(FC): has the bit format CLFFZZZ, where C indicates whether this is a synchronous or asynchronous

frame; L indicates the use of 16 or 48 bit addresses; FF indicates whether this is a LLC frame or a MAC control frame

- Destination Address(DA): specifies the station(s) for which the frame is intended

- Source Address(SA): specifies the station that sent the frame

- Information: contains LLC data

- Frame Check Sequence(FCS): a 32 bit cyclic redundancy check

- Ending Delimiter(ED): indicates the end of frame

- Frame Status(FS): contains the error detection (E), address recognized (A), and frame copied (C) indicators

SYMBOLS

≥16	2	2	4 OR 12	4 OR 12	≥0	8	1	≥3
PA	SD	FC	DA	SA	INFO	FCS	ED	FS

PA = PREAMBLE
SD = START OF FRAME DELIMETER
FC = FRAME CONTROL
DA = DESTINATION ADDRESS
SA = SOURCE ADDRESS
INFO = INFORMATION FIELD
FCS = FRAME CHECK SEQUENCE
ED = END OF FRAME DELIMETER
FS = FRAME STATUS

Figure 13. FDDI MAC Data Frame

b. Basic Operation

A station that wishes to transmit waits until a token frame passes. When a token passes, the station seizes the token by absorbing the token from the ring before the entire FC field is repeated. After the captured token is completely received, the station may begin transmitting frames. Frame transmission continues until there is no more data to transmit or until times expires on the token holding timer. Other stations listen to the ring and repeat passing frames. Each station can check passing bits for errors and can set the "E" indicator if an error is detected. If a station detects it's own address, it set the "A" indicator; it may also copy the frame, setting the "C" indicator. This allows the originating station to differentiate three conditions:

- Station non-existent/non-active
- Station exists but frame not copied
- Frame copied

Figure 14 is provided to illustrate the FDDI ring operation.

2. MAC Services

The local LLC entity is allowed to exchange data units with other LLC entities using the services provided by the MAC layer.

C. FDDI PHYSICAL LAYER SPECIFICATIONS

1. Physical Protocol

In addition to defining the physical layer medium, the physical layer specifications also address the issue of data

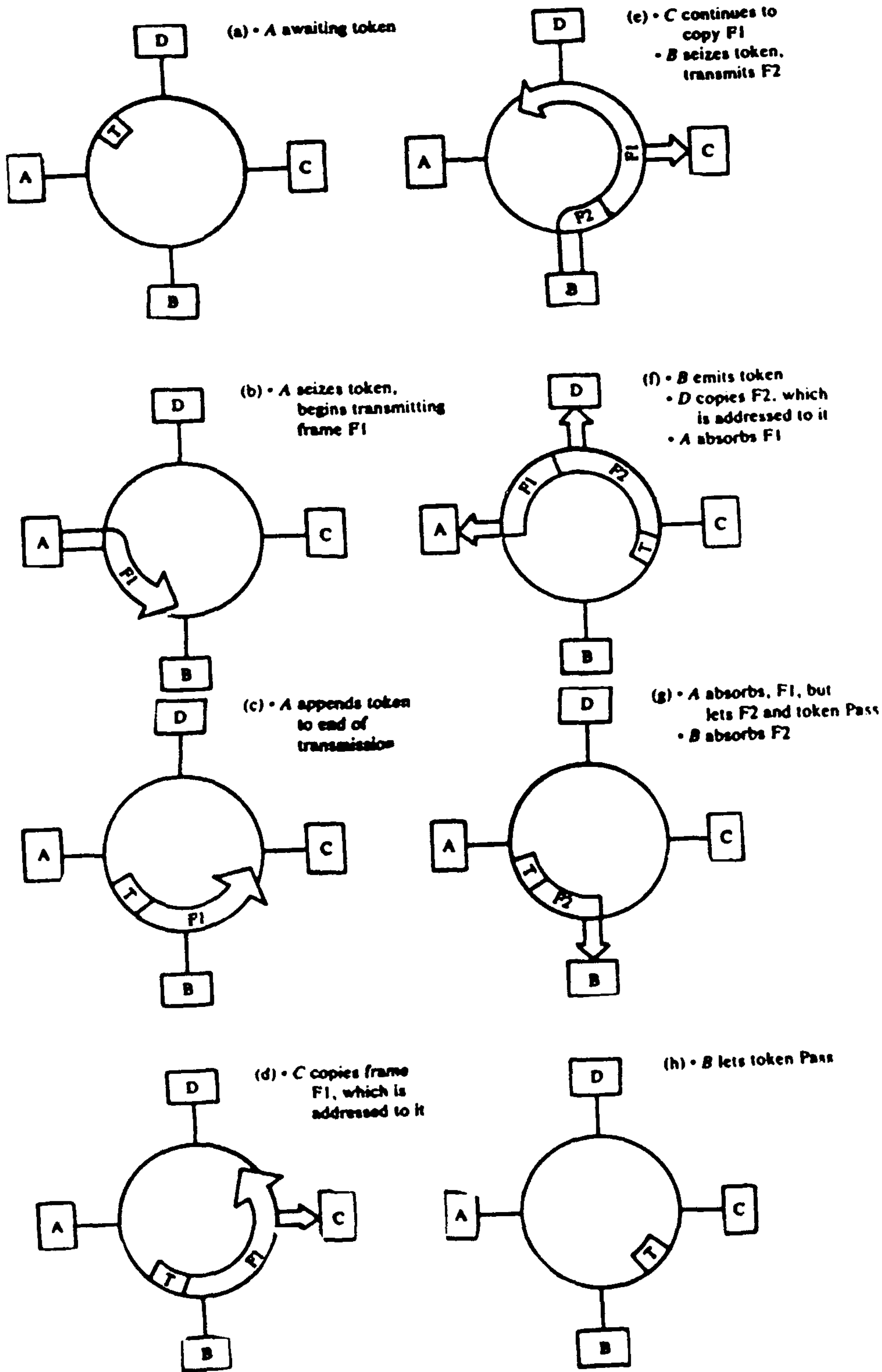

Figure 14. Example FDDI Architecture
Source (Hunninghake, p-94)

encoding.

For transmission as a signal, digital data needs to be encoded. The encoding scheme depends on transmission medium and data rate. Because optical fiber is inherently an analog medium and signals can only be transmitted in the optical frequency range, we would expect one of the popular digital-to-analog encoding techniques (ASK,FSK,or PSK). Although FSK and PSK are possible encoding alternatives, both FSK and PSK are difficult to do at high data rate, and the opto-electronic equipment would be too expensive and unreliable.(Stallings 1987, p-194) Although ASK provides a simple means for encoding digital data for transmission over optical fiber, it lacks provisions needed for the receiver to synchronize its clock to the transmitter. The solution is to encode the binary data, and then present the encoded data to the optical source for transmission. (Stallings 1987, p-195) The disadvantage of this approach is that the efficiency is only 50%.(Stallings 1987, p-196) This is because there can be as many as two transitions per bit time. A signaling rate of 200 million signal elements per second would be needed to achieve a data rate of 100 Mbps. (Stallings 1988, p-200) This represents an unnecessary cost and technical burden.

The FDDI standard, in an attempt to overcome this burden, specifies the employment of a code called 4B/5B. The code works as follows: encoding is done four bits at a time; each four bits of data are encoded into a symbol with five cells such that each cell contains a single signal element (presents or absence of light). In effect, each set of four bits is encoded as five bits. Efficiency is raised to 80%, and 100 Mbps is achieved with 125 Mb. (Stallings 1987, p-198) Synchronization is achieved through a second stage of encoding. Each element of the coding scheme is treated as a binary value and encoded using a technique referred to as Non-return to Zero Inverted(NRZI).

2. Physical Medium

The physical medium specifications, required by FDDI standards, are a fiber optic ring with a data rate of 100 Mbps using the NRZI-4B/5B encoding scheme. The wavelength specified for data transmission is 1300nm. The majority of all fiber transmitters operate at 850, 1300 or 1550nm. Most systems today use a 850nm light source for local data communication. At a distance of about one kilometer and data rates of about 100 Mbps, however, this wavelength begins to be inadequate.

FDDI specifies the use of multi-mode fiber transmission. Today, however, long distance networks rely primarily on single mode fiber. This technology requires the use of laser as a light source rather than light emitting diodes(LED) which are cheaper and less powerful.

D. TOPOLOGY

Topology refers to the structure that provides interconnection of stations attached to the network. The most common topologies for local area networks are the star, ring and bus/tree.

FDDI standards specify the use of a ring topology to be used by its LAN systems. As a means of increasing reliability, the standard also specifies three techniques to be used in the design of its ring architecture. These techniques follow:

- Station bypass: An automatic optical bypass switch allows stations that are in a bad or power-off status to be bypassed
- Wiring concentrator: Interrepeater links all threads through a single site
- Dual ring: Failures result in reconfiguration of the network to maintain connectivity

The dual ring concept is illustrated by Figure 15. Two

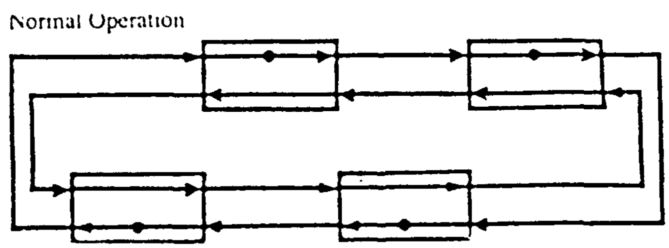

Figure 15. Dual Ring Normal Operation. Source (Stallings 1987,p-201)

links, that transmit in opposite direction, connect neighboring stations. This creates two rings: a primary ring and a secondary ring. The two rings circulate in opposite directions. The secondary ring is idle during normal conditions. If a link failure occurs, stations on either side of the link reconfigure as shown in Figure 16.

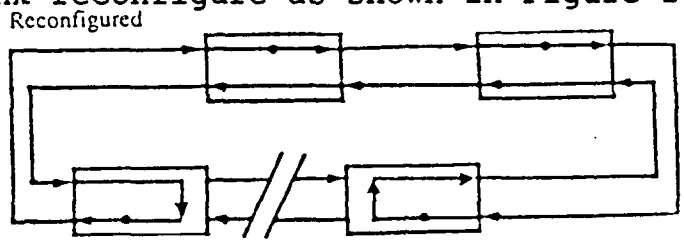

Figure 16. Reconfiguration. Source(Stalling 1987,p-201)

Two classes of stations are defined by FDDI standards as depicted by Figure 17.

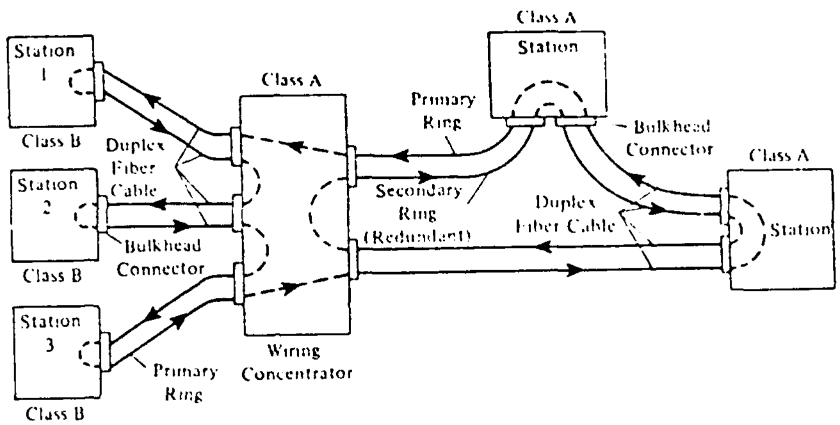

Figure 17. FDDI Ring Architecture. Source (Stallings 1987, p-201)

- Class "A": Both primary and secondary rings connect stations
- Class "B": The station is connected only by the primary ring. Class "B" stations are isolated during failures

As stated earlier, FDDI standards explicitly address the need for reliability. This should be a major concern in the design of any LAN system. Other concerns include:

- Efficient bandwidth utilization
- Bandwidth availability
- Efficient electronic utilization
- Transport and access delay
- Cost, reliability, physical flexibility

E. INTERNETWORKING

Local networks allow efficient high speed communication devices to operate in a small geographical area, such as a building complex or within a building. The only problem with this is the limit to both the number of devices that can be attached to the network and the distance which the network can span. When the need arises for either extending the distance spanned by the network or increasing the number of devices that can be attached on the network, the solutions is to interconnect two or more LANs.

The individual LANs may be interconnected by a backbone ring via gateway, as shown in Figure 18. Generally, the backbone ring is a high speed optical fiber network, such as a fiber distributed data interface (FDDI) network. The gateway performs functions such as routing, storage and forwarding.

The question now is what protocols could be used to provide smooth efficient operation across the gateway. While

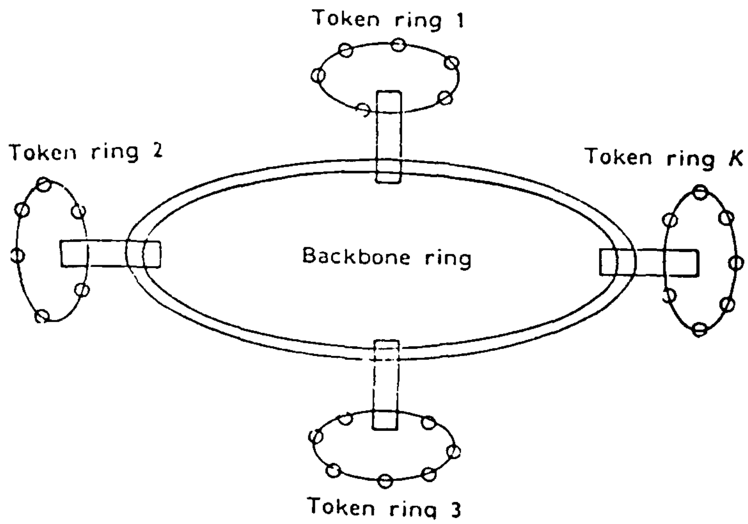

Figure 18. FDDI Backbone Ring. Source (Cheng, p-136)

the discussion of every existing protocol is beyond the scope of this thesis, there is one protocol that is viable and has been demonstrated on a large scale. That protocol is the Transmission Control Protocol/Internet protocol (TCP/IP). TCP/IP form the base technology that connects most research institutions, including universities, corporations and governmental labs. TCP/IP is more than capable of accommodating a wide variety of underlying network technologies. The primary distinguishing features of TCP/IP follow:

- Universal Interconnection: Every computer on the net is assigned an address that is universally known throughout the net. This allows any pair of computers attached to the net to communicate

- Application Protocol Standards: TCP/IP protocols include standards for common applications such as electronic mail, file transfer, and remote login

- End-to-End Acknowledgement: The source and destination machines are provided acknowledgment instead of successive machines along the path

- Network Technology Independence: TCP/IP is independent of any particular vendor's hardware. The unit of data transmission is defined and called a IP datagram. Specifically, TCP/IP specifies how to transmit the IP datagram on a particular network

Figure 19 show three networks interconnected by two gateways. As the size of the internet increases, the task of the gateway to make decisions about where to send packets becomes more complex.

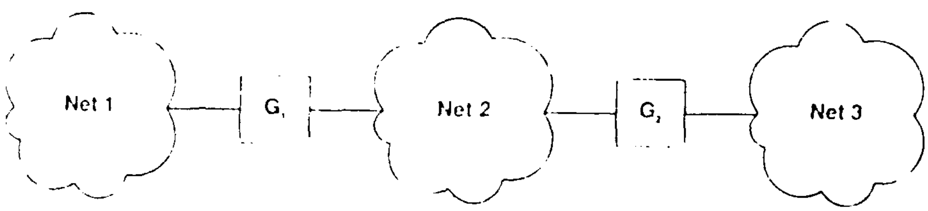

Figure 19. Internetworking via Gateway

From our discussion, one might suspect that gateways, which must know how to route packets to their destination, are very large machines with tremendous primary and secondary storage to hold data about every machine attached to the net. Contrary to this belief, gateways used with TCP/IP are usually minicomputers with little or no disk storage and limited main memories.

The underlying advantage of TCP/IP is that it is extremely flexible in that almost any technology can be used to transfer TCP/IP traffic.

V. SAFENET II

A. INTRODUCTION

In this chapter, an example of a local area network that uses a fiber optic medium will be described. This network, which is employed by the United States Navy, is SAFENET II.

The Survivable Adaptable Fiber Optic Embedded Network (SAFENET) program is an effort by the USN to develop network standards which support the needs of shipboard mission critical computer resources. These needs include increased connectivity, survivability, performance and capacity for future growth.

In an effort to reduce military development cost, SAFENET II is a non-proprietary, open architecture standard based on commercial network protocols and hardware developments.

B. DESCRIPTION

SAFENET II is the second standard intended to define communication subsystems for shipboard computer resources. The standard uses the American National Standard Institute (ANSI) Fiber Distributed Data Interface (FDDI) LAN, which operates at 100 Mbps. The standard also includes the International Standard Organization's (ISO) layers three through seven. The basic elements of SAFENET II is a dual ring token passing LAN which interconnects the attached computers and peripherals, as shown in Figure 20 (Kochanski, p-46).

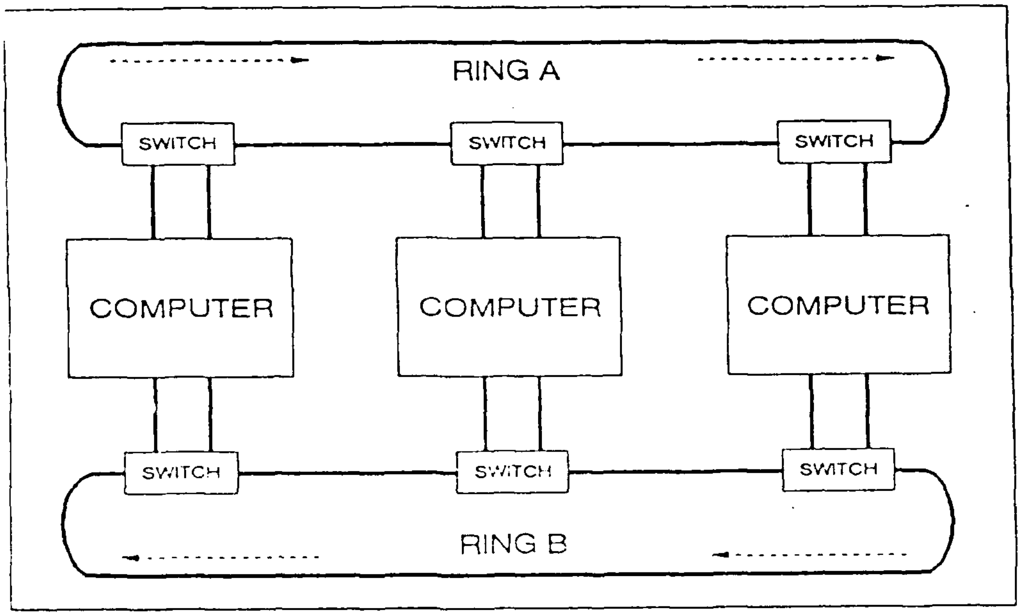

Figure 20. Dual Ring Local Area Network

SAFENET II uses a redundant ring topology as depicted by Figure 21. Each network ring is comprised of a series of trunk coupling units (TCU) and trunk cables, which enables a station to connect to a network ring. Each station is also attached via the fiber optical interface connector(FOIC) by a optical interface cable. The attached stations are further connected to the TCU by an electrical interface cable.

The layout of the physical medium of SAFENET is designed in a manner which optimize both performance and survivability. All optical connections between cables and TCUs are spliced, rather than connected. There are no optical connectors used along the length of the truck cable. The primary and secondary ring truck cables are located apart from each other to avoid simultaneous damage to both rings. These features allow the network to absorb some damage without losing its ability to operate.

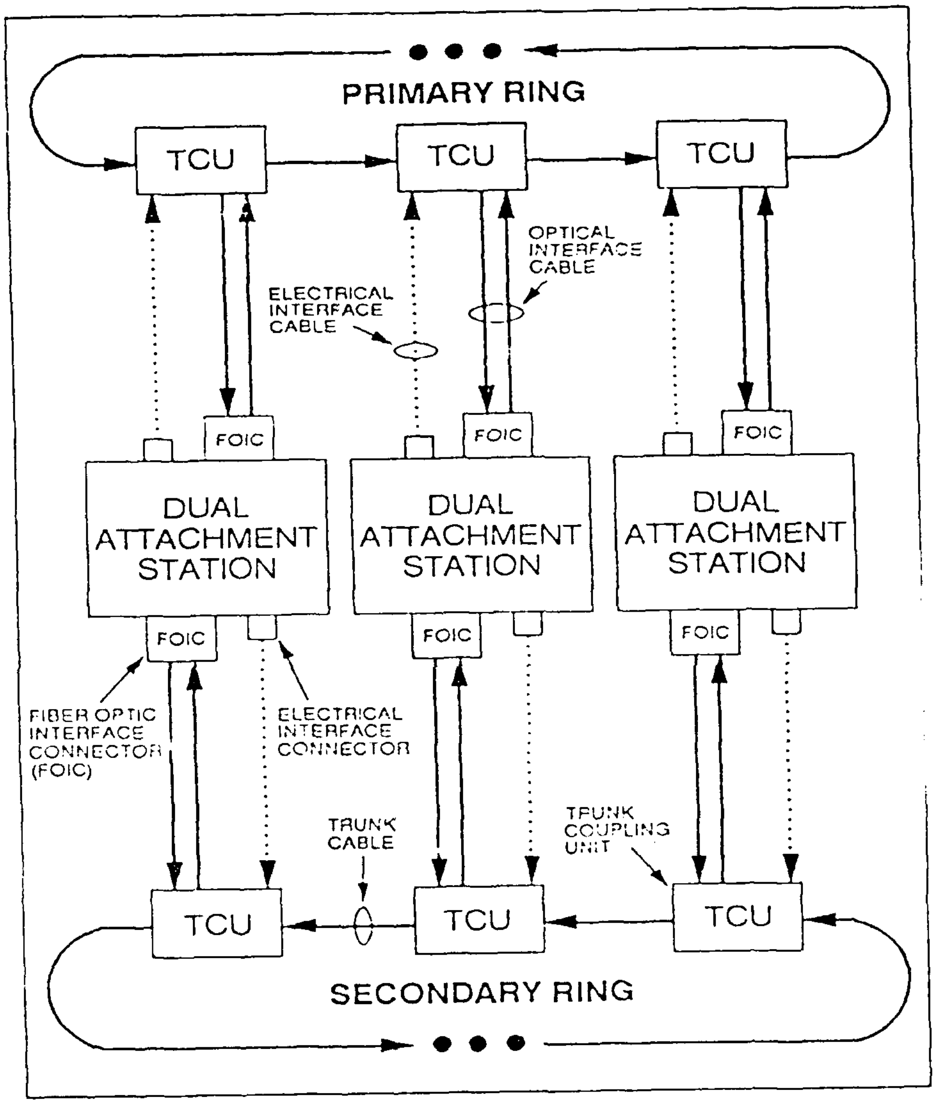

Figure 21. Dual Ring Local Area Network
Source (Kochanski,p48)

The following are the specifications and requirements for the optical components used in the SAFENET physical medium:

- Optical fiber: multimode, graded index,radiation hardened fiber
  Dimensions: core dia. 62.5µn
  cladding dia. 125µn
  coating dia. 250 µn
  Num Aperture: .275
- Fiber optic cable: Attenuation 2.0 db/km @ 1.31µn (max)
  Bandwidth 400 mhz/km @ 1.31 µn (min)
- Fiber optic splices: optical power loss 0.2 db (max)
- Installation repair splices: optical power loss 0.3 db (max)

As stated above, SAFENET's layer protocol is based on the ISO Open System Interconnection (OSI) reference model for computer networks. Each layer of the model is specified by one or more protocols. The complete set of protocols is called the SAFENET profile.(Kochanski, p-46) The profile is divided into three service partitions each of which constitutes a portion of the seven layer OSI reference model.(Kochanski, p-46) These partitions are called user services, transfer services and LAN services. The user services, the protocols they include, and their relationship to the OSI reference model are shown in Figure 22.

The user service partition is that portion of the SAFENET profile through which a user interacts with the network. It corresponds with layers five through seven of the OSI reference model. These services allow the user the ability to interact with, manage and respond to the transfer services.

The transfer services partition is the center of the SAFENET profile. It corresponds to layers three and four of

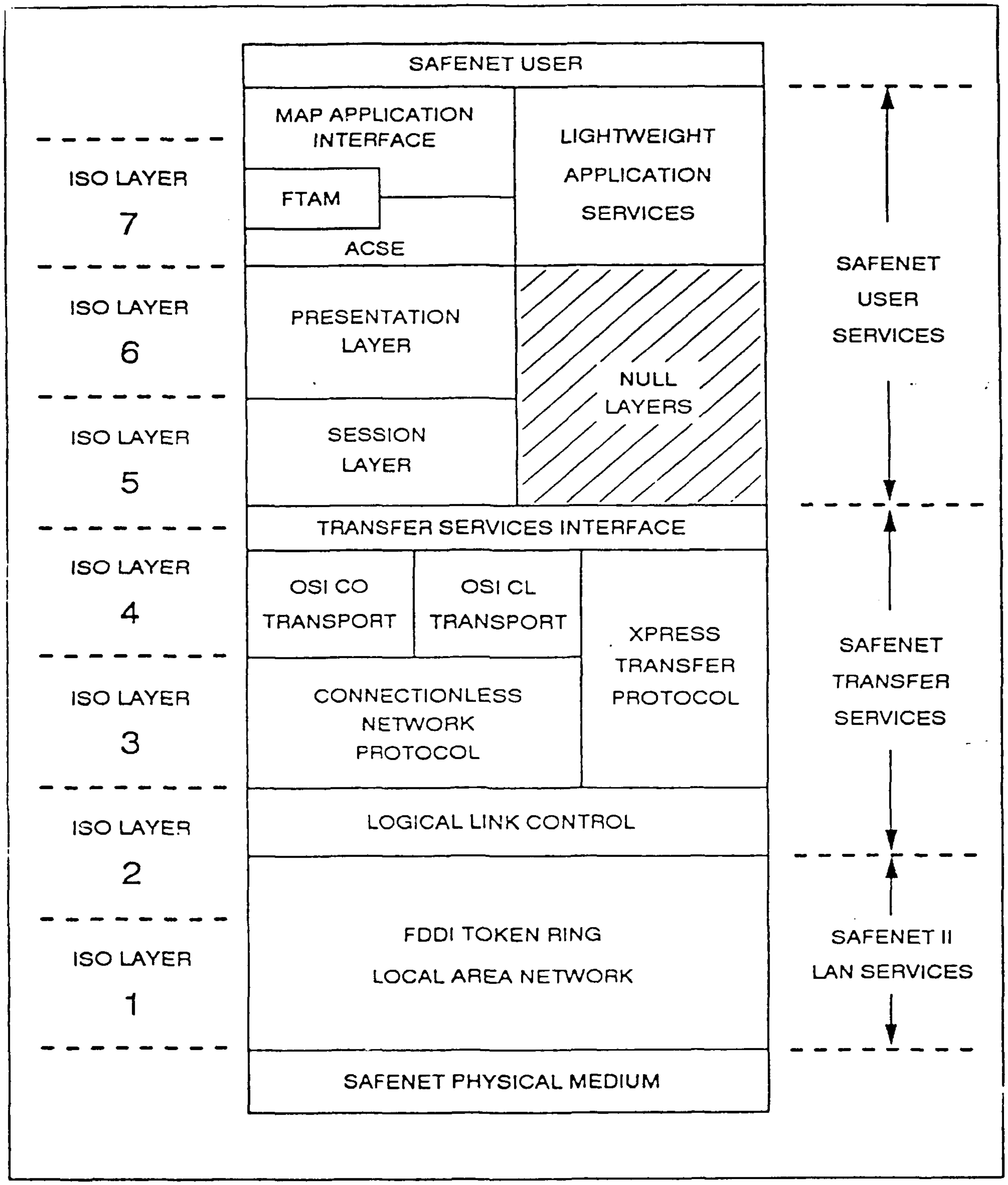

Figure 22. SAFENET II Protocol Profile
Source (Kochanski, p-46)

the OSI reference model and the logical link control sub-layer of the data link layer. These services provide reliable communication mechanisms to the SAFENET user.

The LAN services partition performs the actual data transfer. It corresponds to the physical layer of the OSI reference model and the medium access control sub-layer of the data link layer. The LAN services provide the ability to get data on and off the physical medium.

C. SAFENET II PROTOCOL SUITES

The architecture can also be viewed in terms of its different protocol suites. There are three SAFENET protocol suites:

- OSI protocol suite
- Lightweight protocol suite
- Combined protocol suite

The implementation classes are defined by these suites. Figure 23 shows the protocol suites, the communication protocol they include and the communication protocol common to all suites. The combined protocol suite is not shown as a distinct entity because it is the union of the other two suites. Figure 23 also shows the different communications paths between a user and the local area network.

The OSI protocol suite provides full OSI compliant networking to systems that require it.(Kochanski, p-47) The

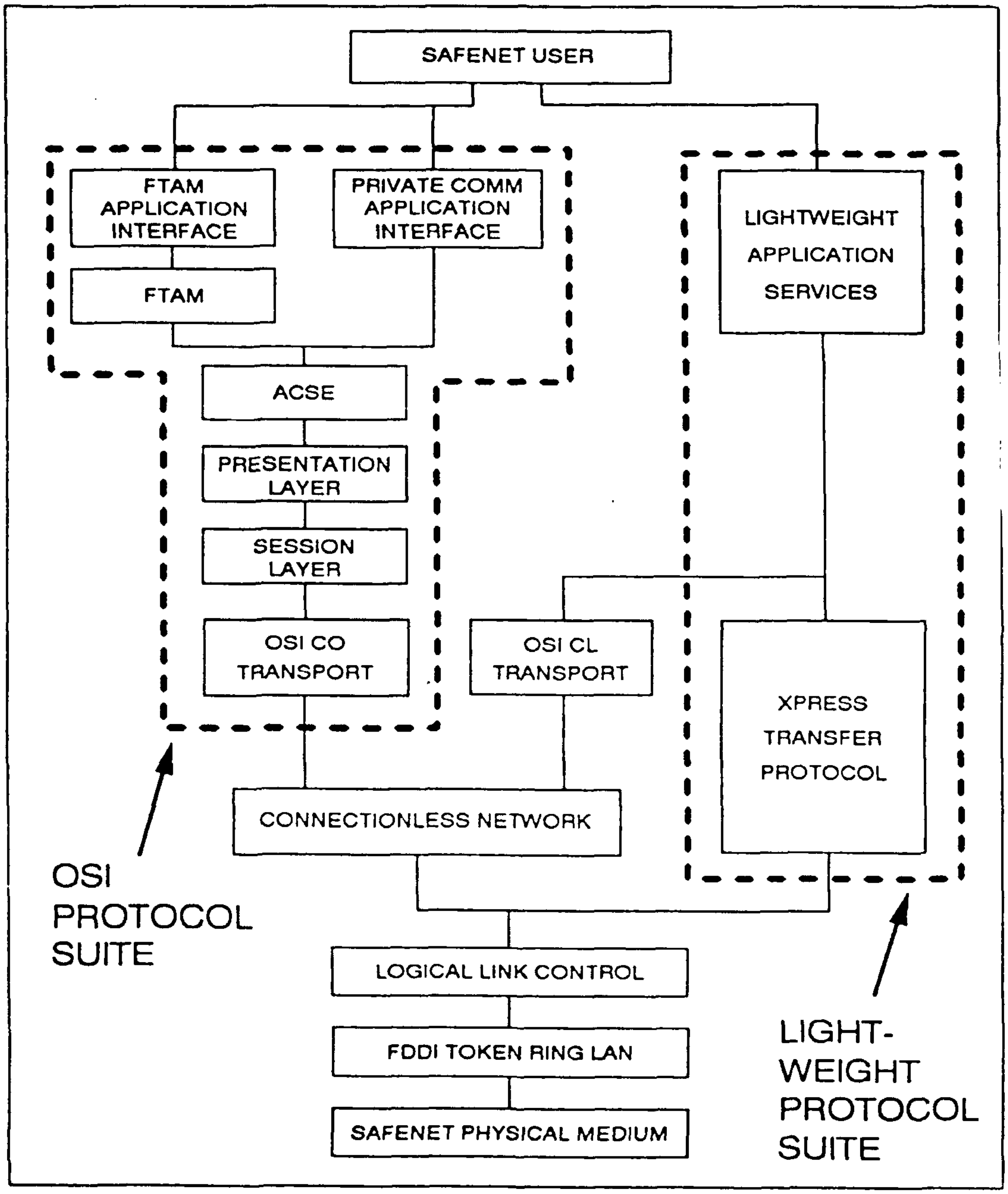

Figure 23. SAFENET II Protocol suites

communications protocols are taken from the manufacturing automation protocol (MAP) and the ISO connection-oriented transport protocol.(Kochanski, p-47) The OSI protocol suite provides access to these protocols through the MAP application interface.(Kochanski, p-47) Directory services and network management capability are also included in this suite.

The lightweight protocol suite provides real time data transfer to systems which require it.(Kochanski, p-47) The communication protocols used by this suite are the Xpress transfer protocol (XPT) and the ISO connectionless transport protocol. Access to these protocols is provided by the lightweight protocol through a SAFENET defined lightweight application service definition.(Kochanski, p-47) No defined network management capabilities are provided by this suite.

The combined protocol suite is essentially the union of the OSI and lightweight protocol suites.(Kochanski, p-47) This suite includes all the protocols, services and capabilities of both the OSI and lightweight suites. Additionally, network management capability is provided by this suite for those protocols contained with the lightweight protocol.

VI. SUMMARY

A. TECHNOLOGY

Fiber optic technology for LAN applications continues to mature. As a transmission medium, it has proven to be extremely effective in the LAN industry. Commercial vendors now are able to offer their customers LANs that can serve as high capacity backbone networks and multimedia communication systems supporting data, voice, facsimile, image and video traffic. This technology brings to the communication arena a new level of excitement.

As discussed earlier, one of the standards set in place by ASC X3T9, as a mean of standardizing high speed LANs, is the Fiber Distributed Data Interface standard. FDDI, like the IEEE 802.5 standards, employs the token ring algorithm. The major difference is the way in which capacity is allocated on the ring. The FDDI approach is designed to take advantage of the high speed (100 Mbps) of its ring and maximize efficiency.

Another technology that has revolutionized the communication's industry is internetworking. This technology allows a society that revolves around information exchange to function as a single unified communication system. Internetworking has changed the way we view the world by shrinking geographic distances and forming new communities of people who interact frequently. It is because of this frequency that fiber optic technology comes at a crucial time. Just as the demand for higher capacity interconnection has begun to exceed the capacity of existing backbone networks, fiber makes it possible to substantially increase the bandwidth of interconnections.

Because LAN technology employing fiber optics offers many inherent advantages to its users, it proves to be a more than viable tool for all types of communication environments. This is evident by the U.S Navy's use of SAFENET II. SAFENET II standards define a communication subsystem which uses a LAN for intercomputer and computer-to-peripheral data transfer. The system is part of the Next Generation Computer Resource (NGCR) program, which is responsible for developing standards for future shipboard computer hardware and software. SAFENET II was designed to meet the increased connectivity, survivability, performance and capacity needs for future system growth for systems employed by the U.S. Navy. It supports the fact that LAN technology is rapidly becoming the preferred communication method for every facet of the communication environment.

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